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SIMPLY FOCUSED NEUTRINO BEAMS

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Abstract

This paper gives a description of a neutrino beam designed specifically to provide neutrino spectra that can easily be calculated from a hadron production spectrum. The beam uses quadrupole focusing with a limited angular acceptance (2 mrad) so that only forward yields are important in determining the neutrino flux spectra. A facility to measure the forward production of pions and kaons is an explicit part of the design.

The Beam Design

A schematic diagram of some of the elements in the Fermilab muon beam is shown in Fig. 1. Only that part of the muon beam that is pertinent to neutrino experiments is shown in the figure. As a neutrino facility the beam is divided into two parts: (1) The quadrupole triplet located just downstream of the target is used as the focusing element for the neutrino beam. This is the only element that is actually required for a neutrino run; (2) The beam elements and Cerenkov counters downstream of the decay pipe are used as a double-bend spectrometer to measure the forward production of pions and kaons from the neutrino target. A target located in the so called bypass beam provides for yield measurements at alternate angles. From the yield measurements, the ν, $\bar{\nu}$ flux can be calculated by tracing the π, K rays through the quadrupoles and allowing for their decay. The shape of the neutrino spectrum is adjusted by varying the quadrupole tune.

A distinct advantage of the beam lies in its ability to suppress low energy flux and enhance the high energy region. Thus high energy interactions can be studied under conditions of a suppressed low energy background. The high energy flux that can be obtained is comparable to that of a horn focused beam.

Another distinct advantage of the beam lies in its ability to flatten the energy dependence of the neutrino flux. This is perhaps particularly important for total cross section measurements to minimize the systematic bias inherent in a steeply falling neutrino spectrum.

Some pertinent properties of the beam can be summarized: (1) The beam is not particularly sensitive to the angle at which the proton beam hits the target since production spectra tend to be relatively flat in the forward direction. An accuracy of 0.5 mrad in the targetting angle is quite sufficient; (2) The magnification of the triplet is about fifty in each plane. Thus, a displacement of the beam of 1 cm at the target will displace the beam by 0.5 m at the detector.

Flux Distributions

Pion and Kaon yields were measured from a neutrino production target using the muon beam as a spectrometer. (See paper presented at this conference.) From these measurements neutrino distributions have been calculated for various beams and are presented in Fig. 2. In the notation used in the figure, the triplet is said to be tuned to 200 GeV if it is set to focus point to parallel at that energy.

The distributions presented in the figure are for ideal conditions. That is, no account has been made for scattering or production sources in the beam other than at the target. Measurements made with the target removed in the broad-band beams at Fermilab indicate that 25% of the neutrino flux comes from these sources. All two-thirds of this flux is presently understood, but these corrections have not yet been applied to the neutrino distributions.

A feature of the triplet beam is its ability to shape the neutrino spectrum to meet the requirements of the experiments. Thus, for example, the 200 GeV beam has a neutrino spectrum that is nearly independent of energy for momenta between 100 and 200 GeV/c. The overall distribution is also considerably less energy dependent than for other beams. This is a good spectrum for a total cross section measurement.

Bare Target Beams

Also given in the flux distributions are spectra for so called bare target beams - Neutrino beams that are completely unfocused. An advantage to running an experiment with such a beam is that biases are minimized in the flux calculation: Only the production spectrum and decay kinematics are required to calculate the neutrino energy distributions. The flux from such a beam is, of course, much lower than for other beams. However, for a 200 ton detector and 10^{13} protons on target, the event rate is about one per pulse, which is a useable event rate. Operation with a bare target beam is pertinent to total cross section measurements and measurements of the ratio of $\sigma_{\bar{\nu}}/\sigma_{\nu}$.

Conclusions

Because the quadrupole triplet beam does not distort the ν and $\bar{\nu}$ spectra relative to each other, it will be particularly useful in determining the ratio of $\sigma_{\bar{\nu}}/\sigma_{\nu}$. Because it can produce a relatively flat energy spectrum it will be valuable in measurements of the total cross sections. At the Fermilab facility, it also has provision for its own flux measuring spectrometer. Combined with bare target beams, sign-selected beams, and horn focused beams, neutrino spectra with a variety of individual properties are available at Fermilab for a comprehensive program of neutrino physics.

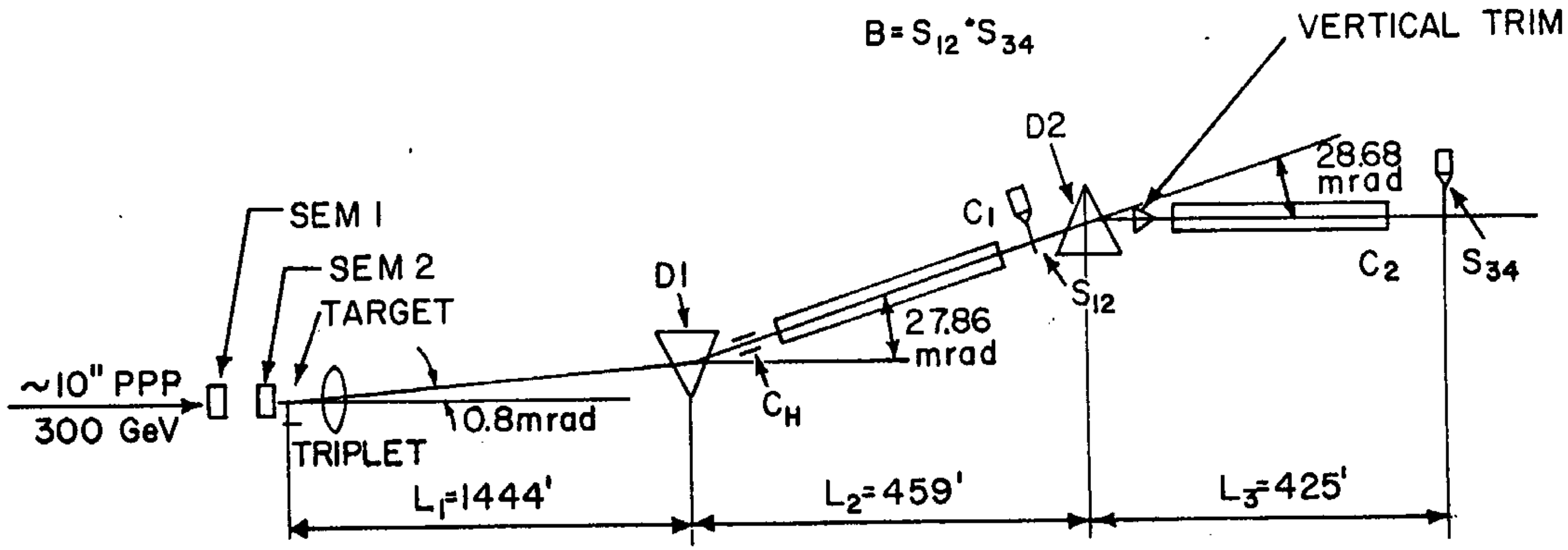

Figure 1: The Fermilab muon beam as it is adapted for neutrino physics. The quadrupole triplet focuses and shapes the neutrino spectrum; The rest of the beam is used as a double-bend spectrometer to analyze the hadron production spectrum.

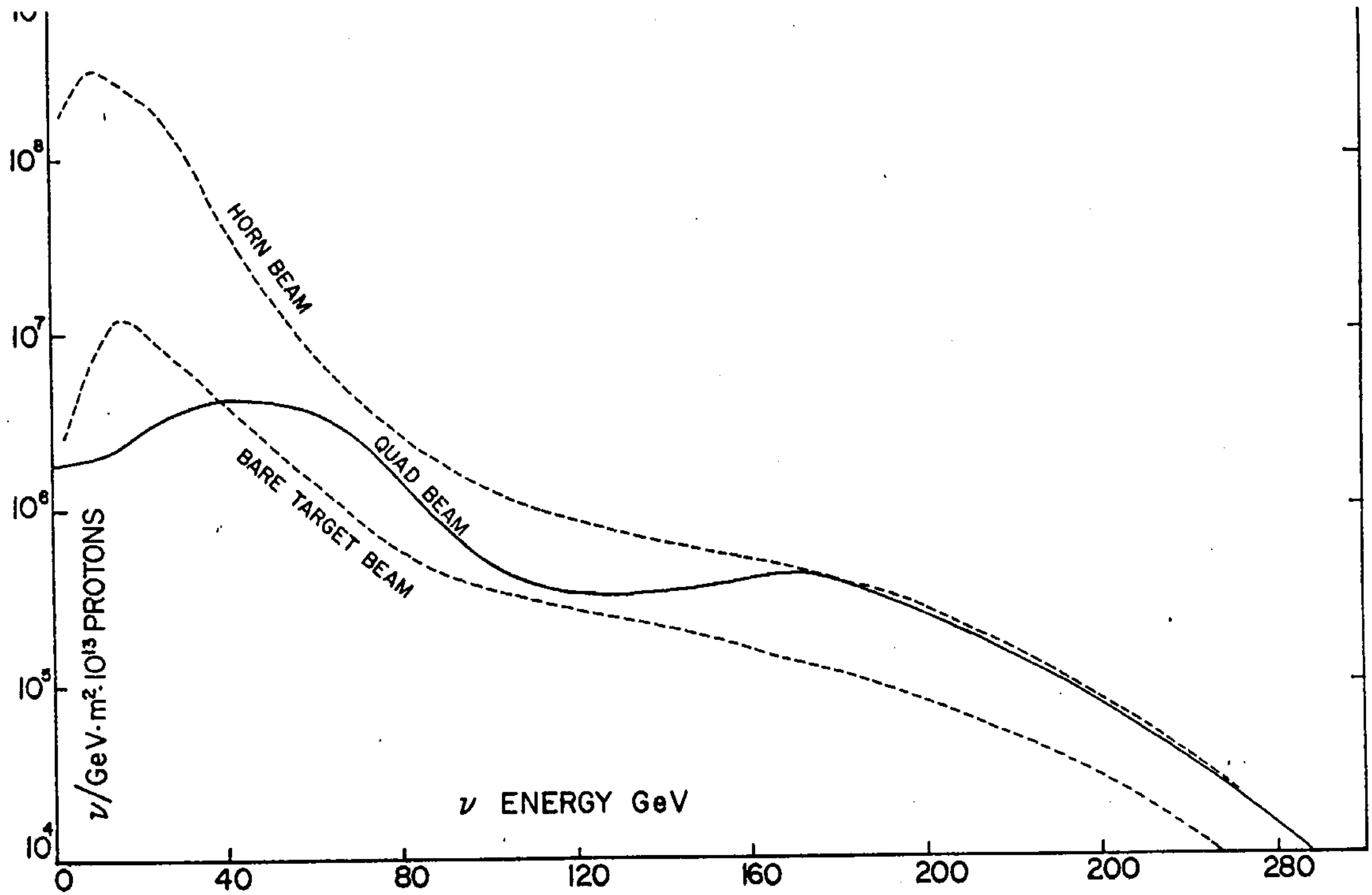

Figure 2: Neutrino spectrum for horn, quadrupole and bare target beams. The quadrupole triplet is set to focus point to parallel at 200 GeV. The calculation is based on measured hadron production spectra.

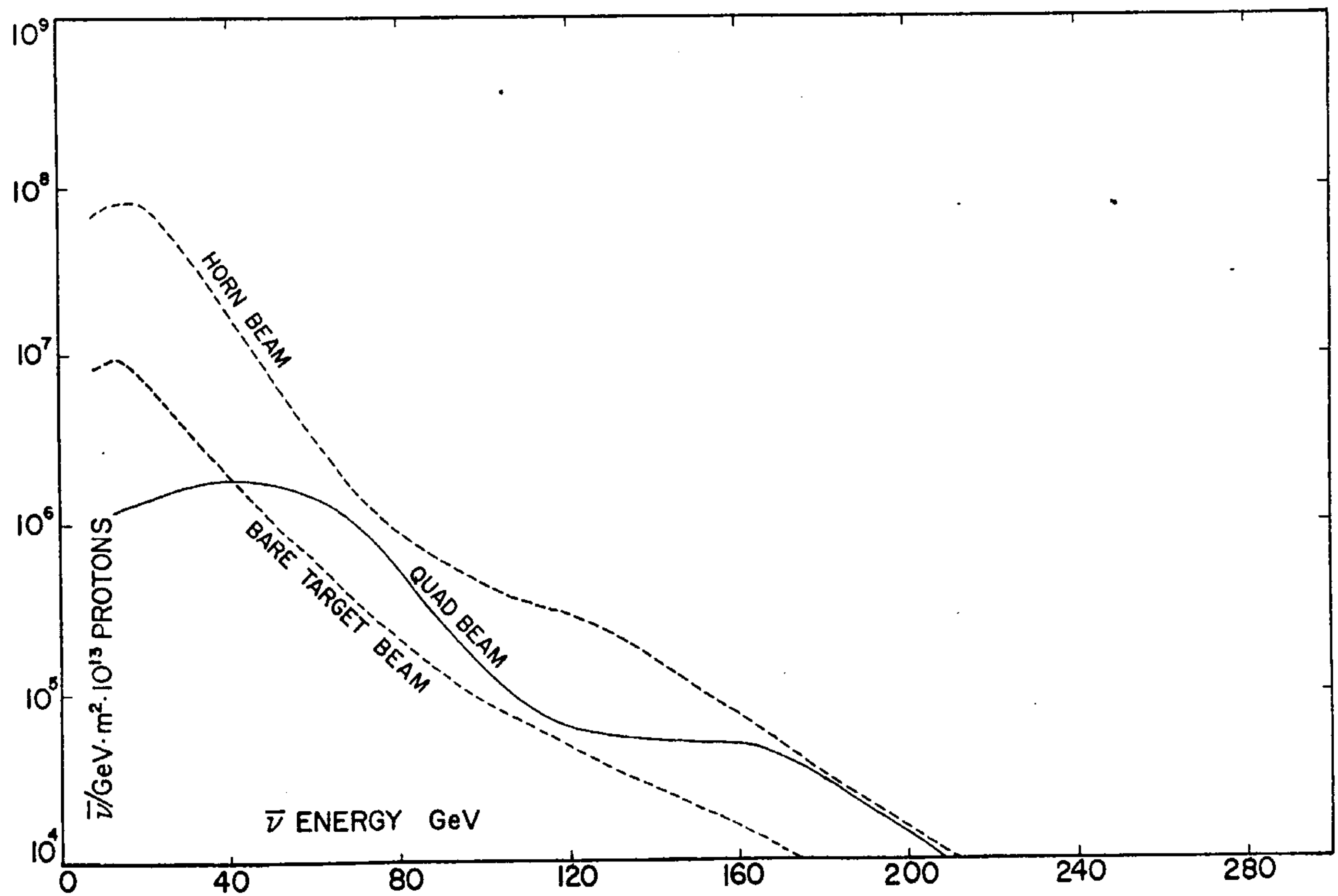

Figure 3: Same as Figure 2 for antineutrinos.